InVisage

Quantum Dot Based Imagers for Multispectral Cameras and Sensors

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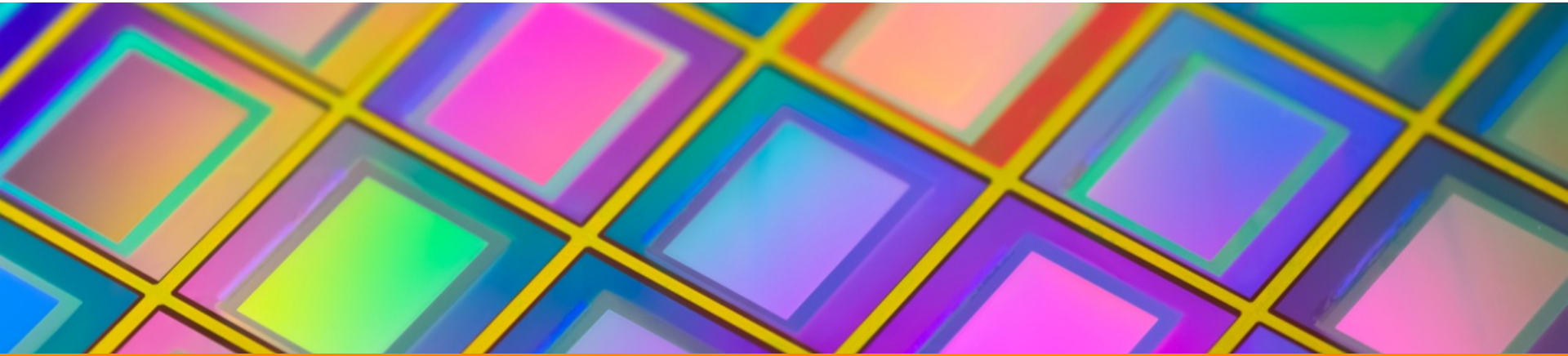


Quantum Dot Based Imaging

- Introduction: Challenges for Silicon in Visible and Infrared Spectra
- Making QuantumFilm
- QuantumFilm Sensor Structure
- Advantages of Visible QuantumFilm
- Advantages of NIR QuantumFilm
- Conclusion and Q&A

Challenges for silicon CMOS cameras in visible light

Digital imaging compromises quality for compactness

Backlit/Shadow
limited dynamic range

Moving camera
rolling shutter effect

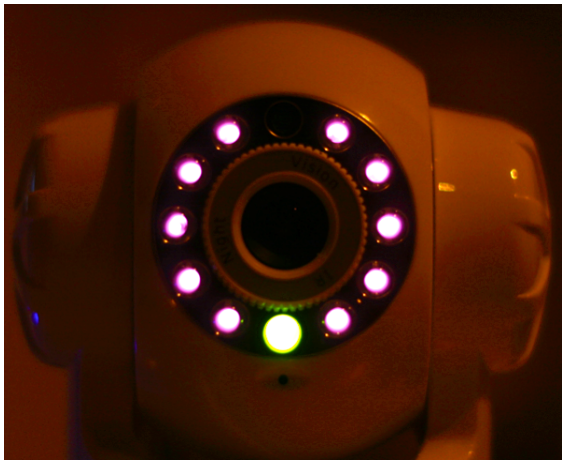
Low light
not very sensitive

Reason: Physics - silicon is a poor absorber of light

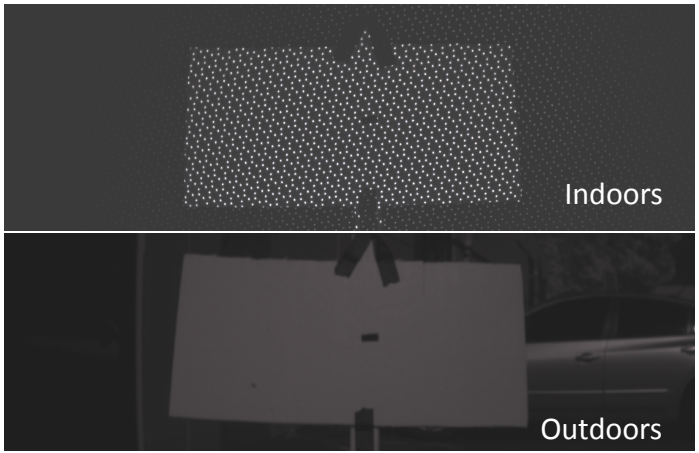
Challenges for silicon CMOS cameras in infrared light

IoT device potential/reach limited by poor silicon NIR performance

Low Resolution/ Sharpness



Active illumination is still visible (red glow)



Can't Perform Outdoors

Solution: QuantumFilm

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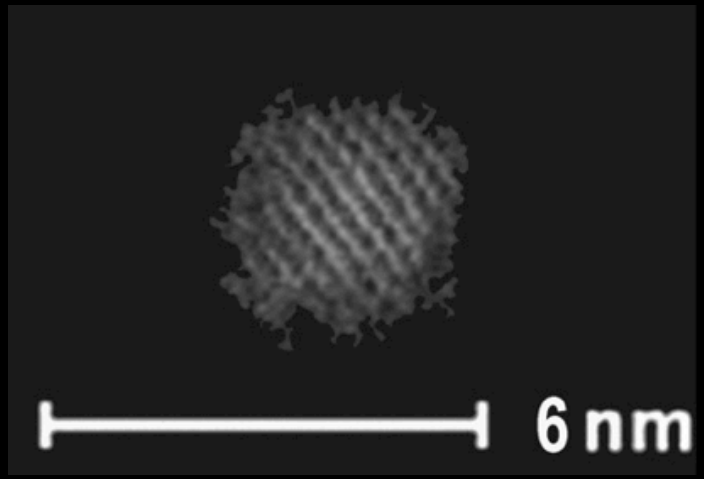
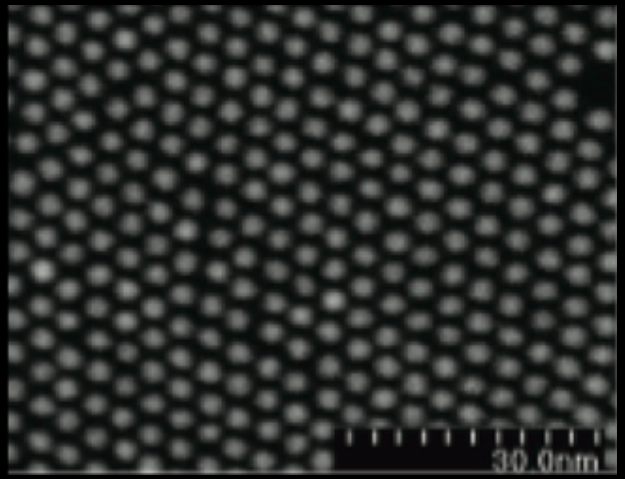
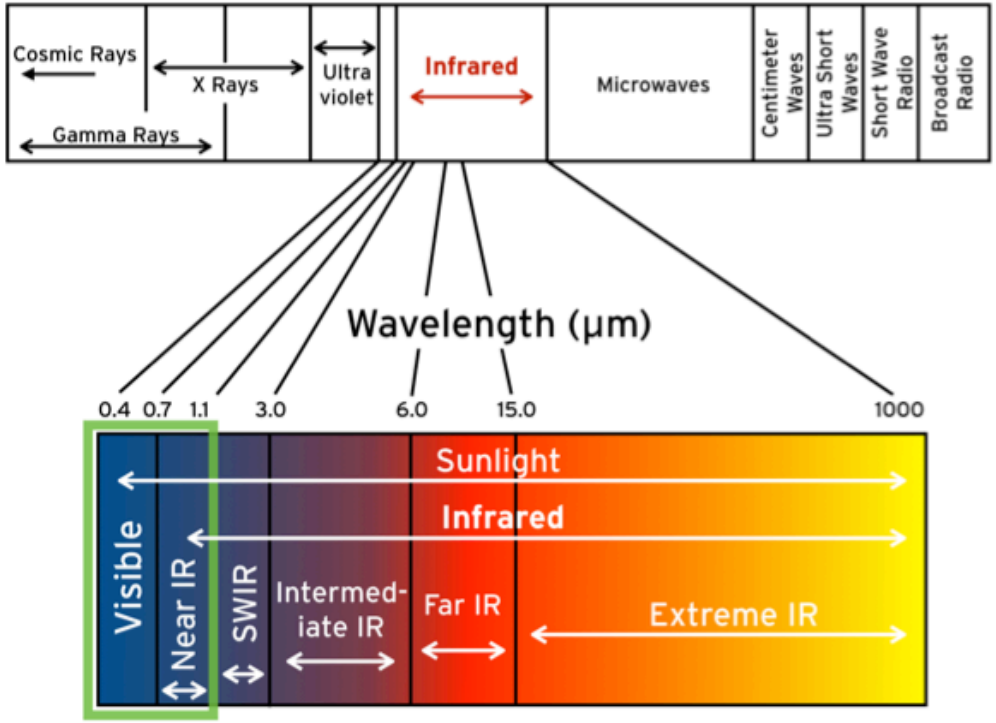
From Quantum Dots to QuantumFilm™





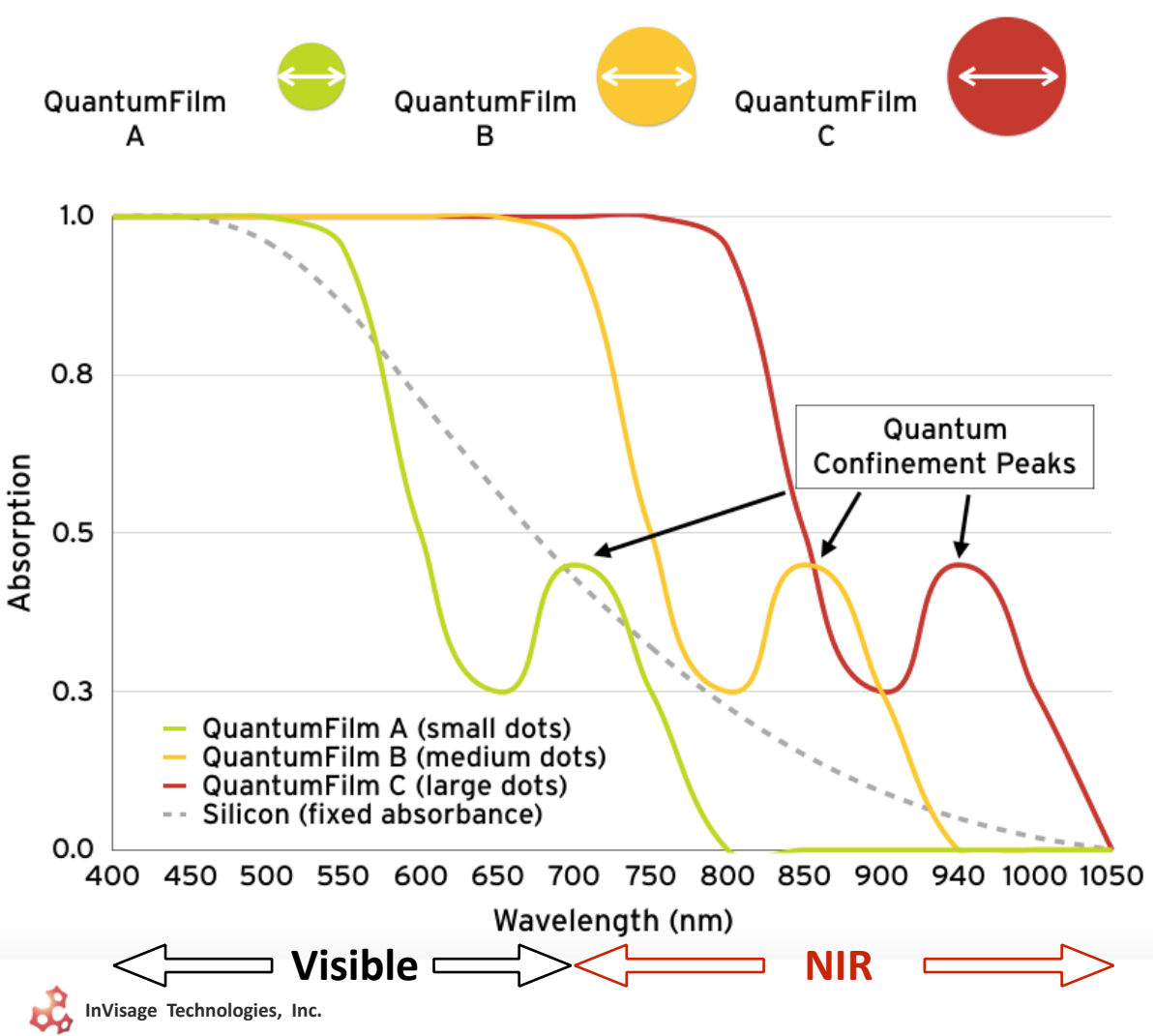
QuantumFilm is Multispectral: Sensitive to visible and near infrared (NIR) light

- QuantumFilm demonstrates superior absorption in visible and NIR light ranges in the electromagnetic spectrum (400-1100 nm, green box).

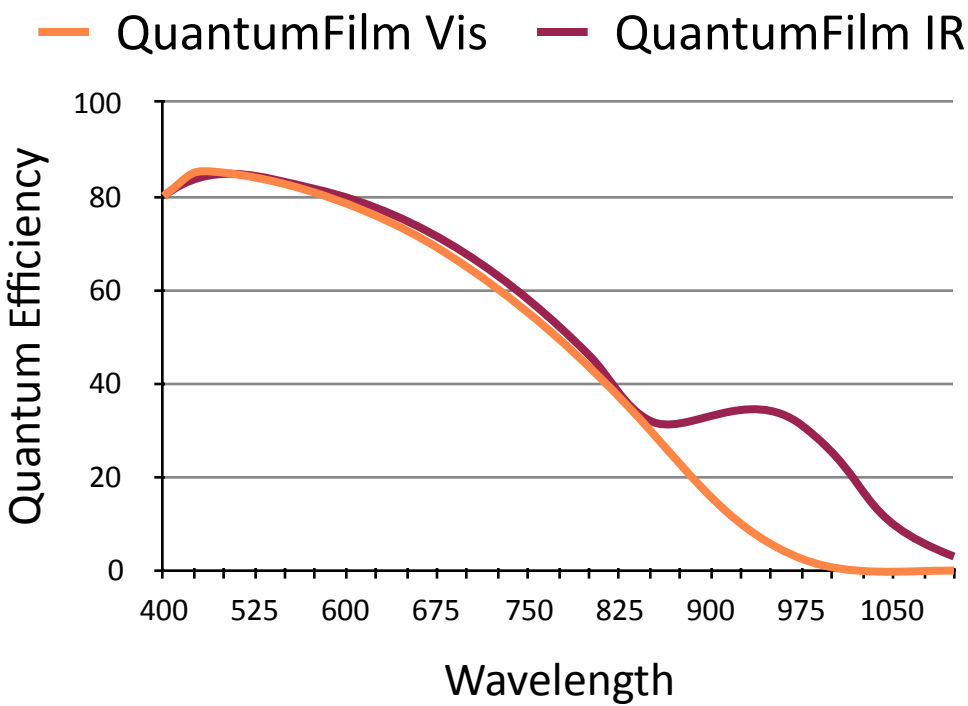


QuantumFilm's spectral sensitivity is adjustable

- Quantum dot size defines material bandgap & absorbance properties across spectrum
- Dot size can be selected to maximize light absorbance in NIR range
- Silicon has fixed absorbance properties across spectrum; its absorbance falls rapidly in NIR range

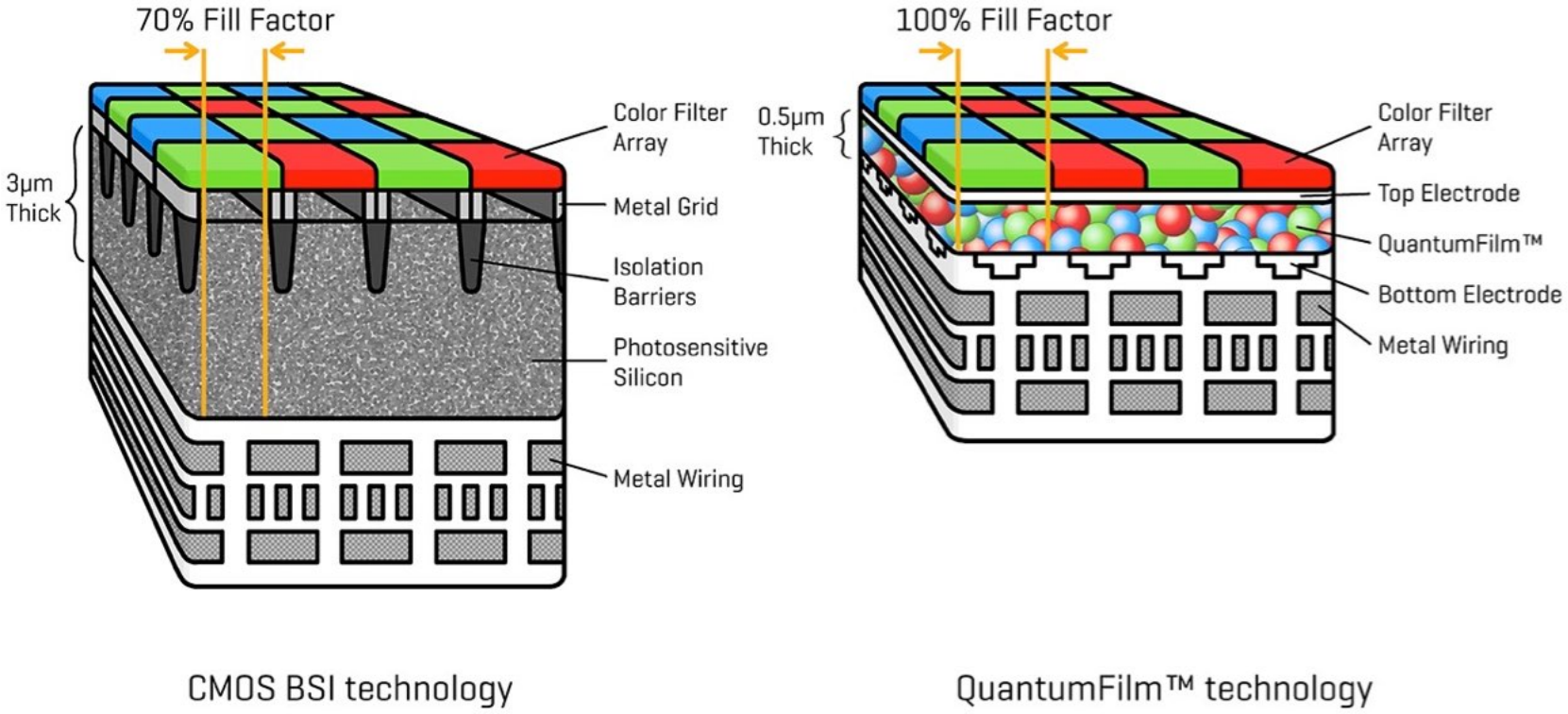


Quantum Dots Capture a Wide Spectrum

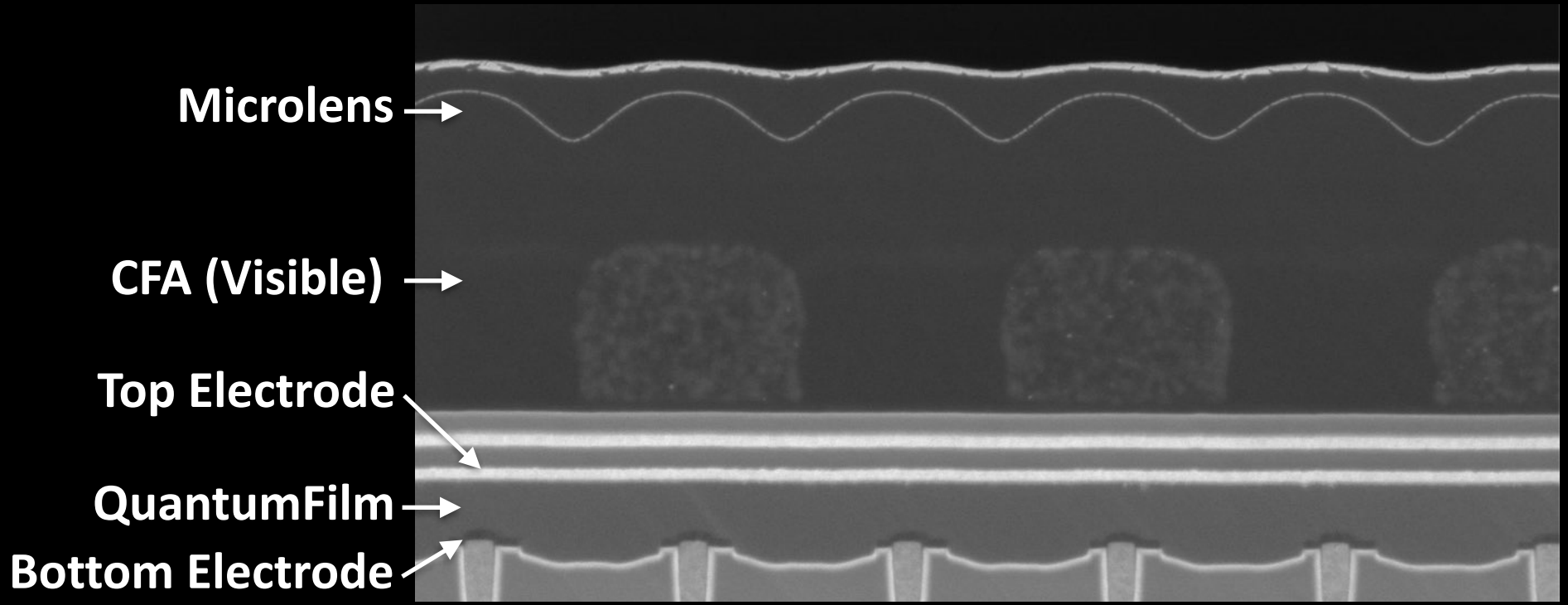


- Quantum Efficiency (QE) = Percentage of photons detected by a sensor and converted to electrons
- Quantum dots have extremely high QE in **both the visible and IR** spectra.

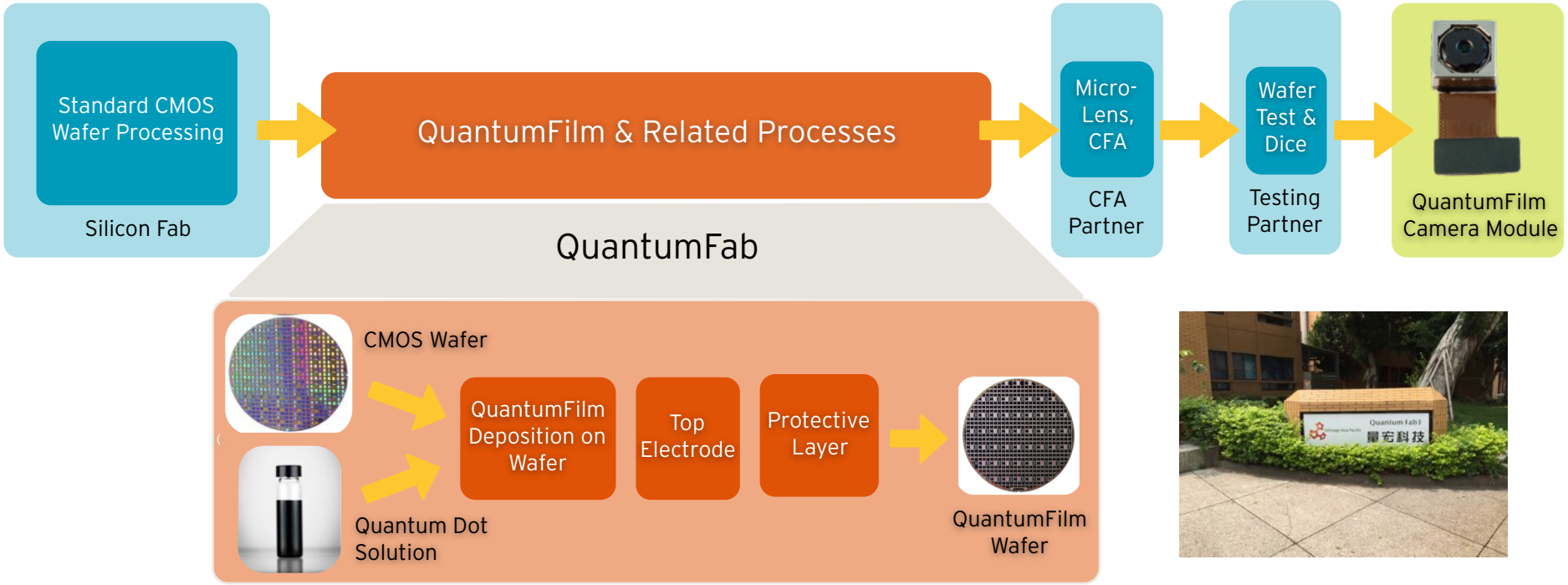
BSI technology vs QuantumFilm™



QuantumFilm Cross-Section

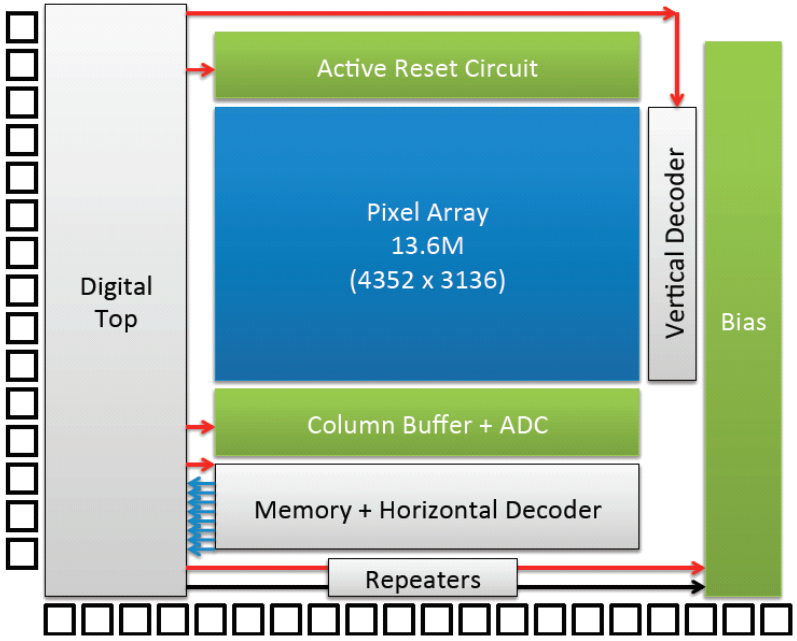


QuantumFilm Sensor Manufacturing Supply Chain



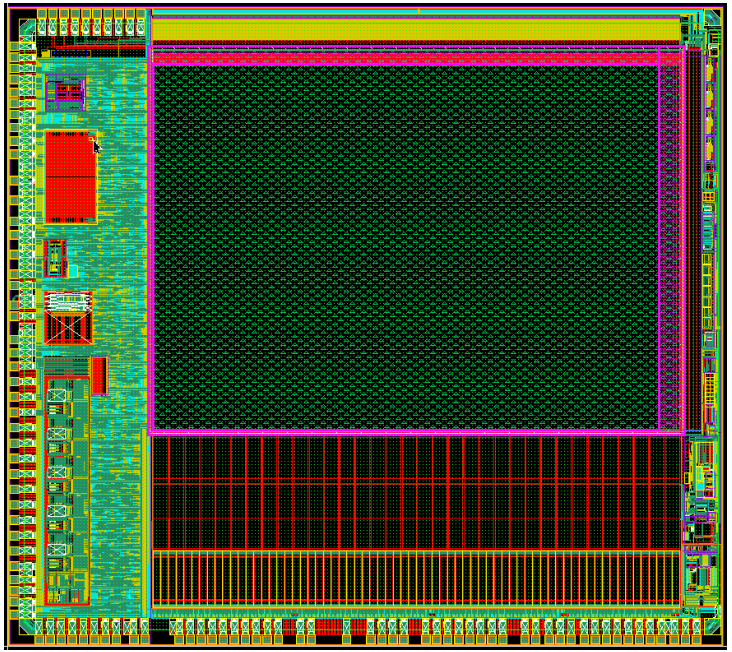
Sensor Typical Chip Architecture

Block Level Diagram



- Clocks
- Serial I/F
- Data

Layout of a 13MP sensor



QuantumFilm Advantages vs. Silicon in Visible

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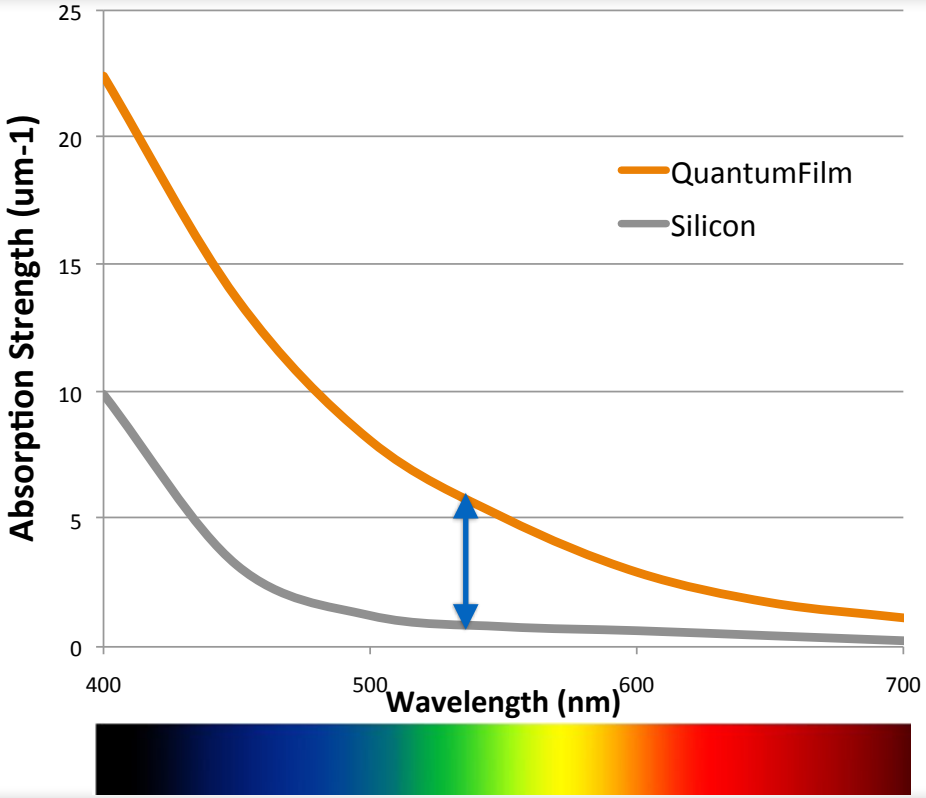
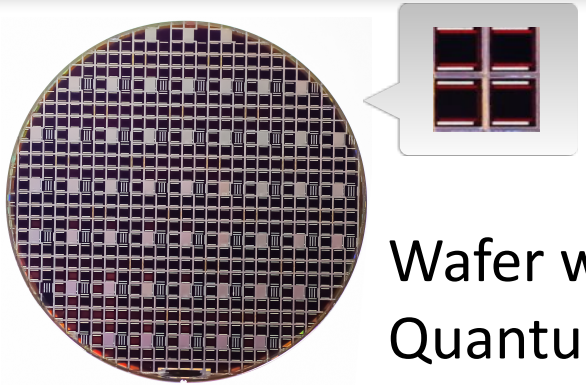
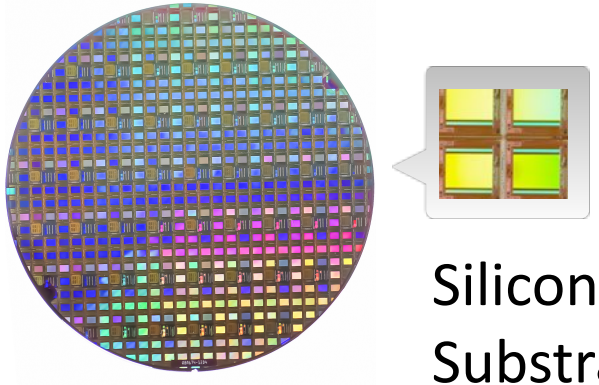
Visible QuantumFilm Advantages:
Sensitivity - QuantumFilm absorbs 8X more light than silicon





Wafer with QuantumFilm

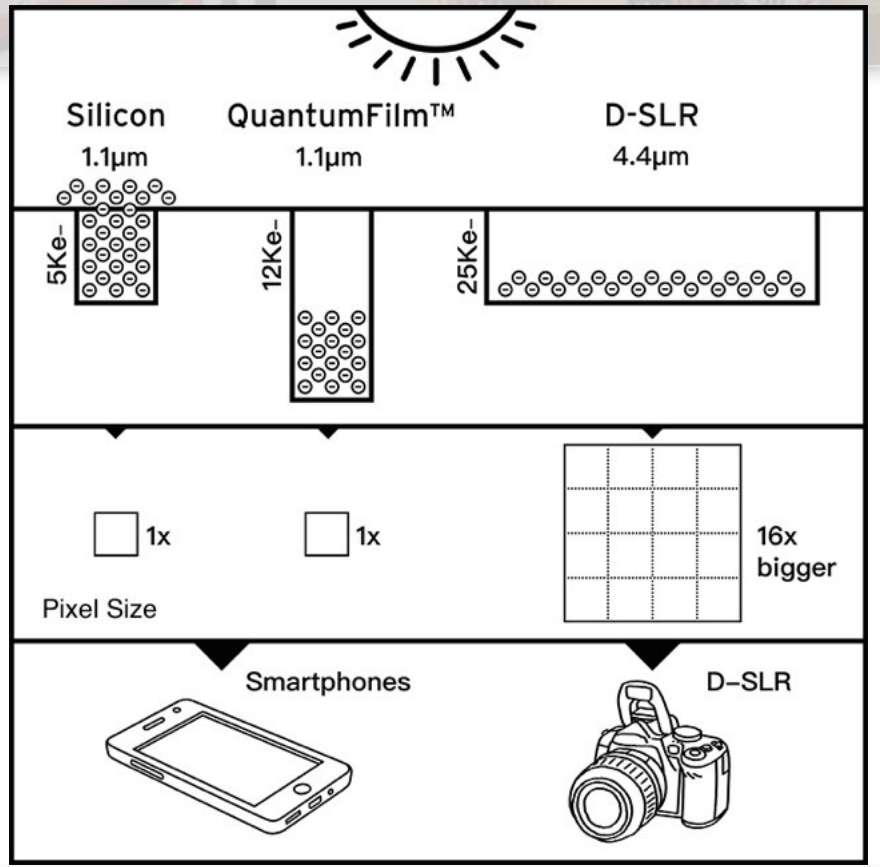


Silicon Substrate

Visible QuantumFilm Advantages: Larger Full Well Capacity

Higher Full Well Capacity (FWC) —> Increased Dynamic Range

- QuantumFilm FWC = **12,000 e^-/1.1 µm pixel**
- Silicon FWC = **5,000 e^-/1.1 µm pixel**



Visible QuantumFilm Advantages: in-pixel dynamic range compression

Native Non-Linear Response —> Increased Dynamic Range

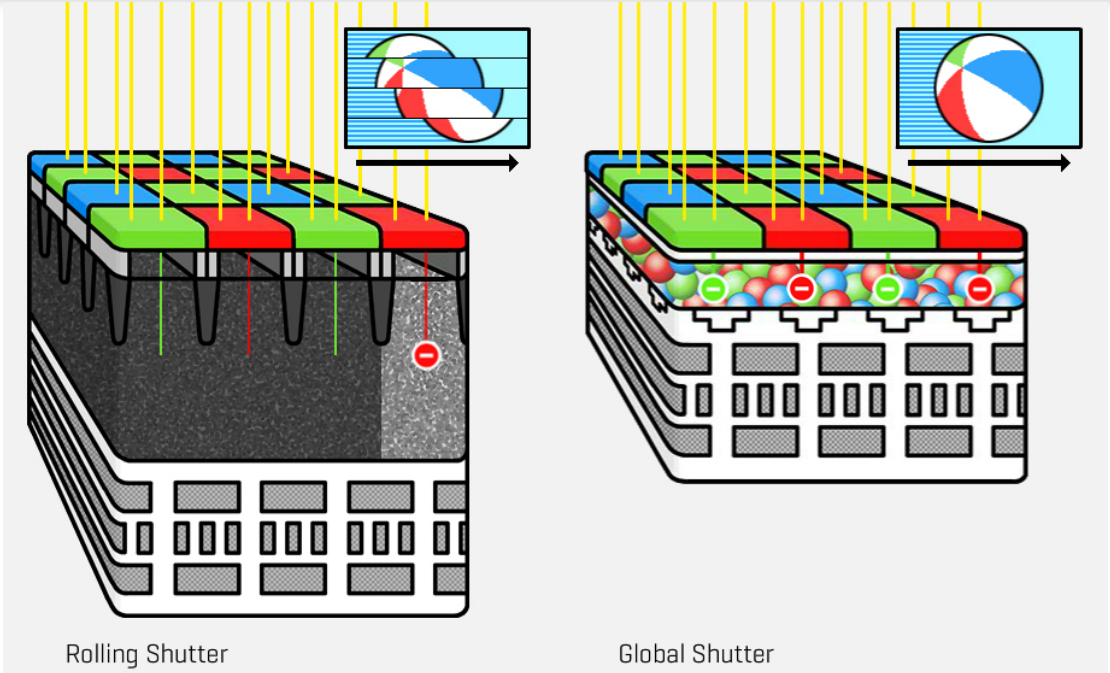
- QuantumFilm can respond to light in a **linear or non-linear** fashion
- Non-linear curve matches the curve of old cameras films in the highlights and can be linearized to reveal details

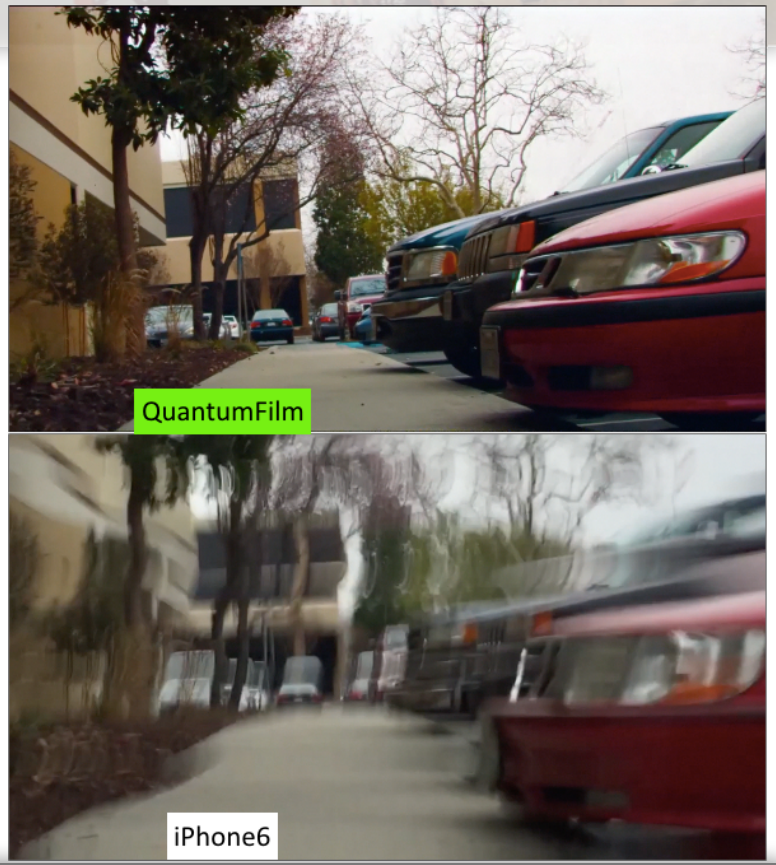
High quality phone with Silicon CMOS camera

Kodak Film

QuantumFilm

Visible QuantumFilm Advantages: Global Shutter with Small Pixels





High Resolution + Global Shutter

QuantumFilm Advantages vs. Silicon in Near Infrared

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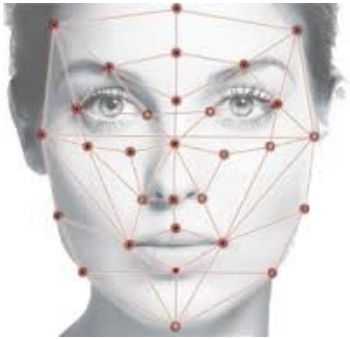
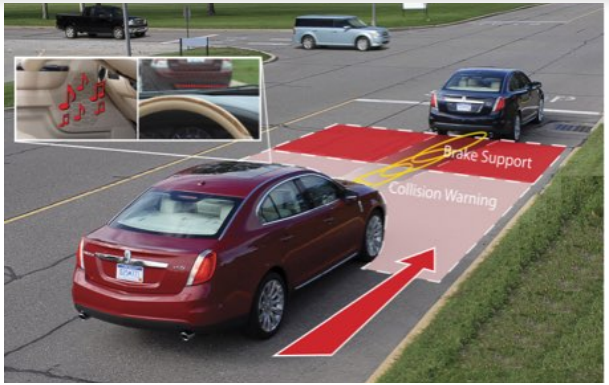
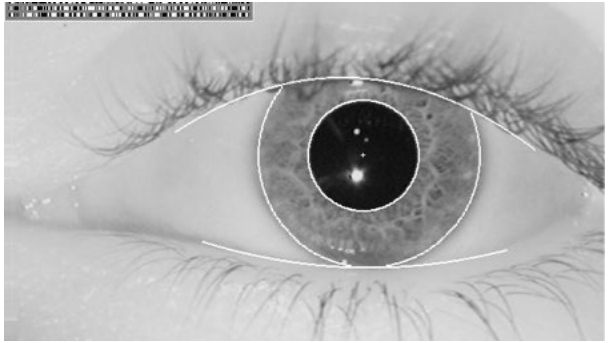
In 2020, 30B IoT devices will transform our lives



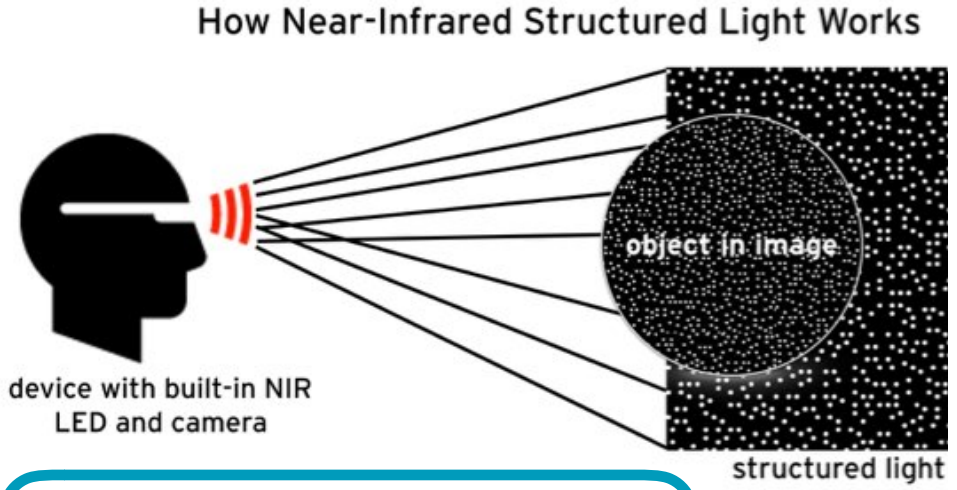




Source: IDC

Why IoT and machine vision need infrared

- **Structured light** or active illumination senses **depth and distance**
- IR light:
  - is unobtrusive - **invisible to the human eye** beyond 880 nm
  - can be made **visible to IoT devices**, even in the dark



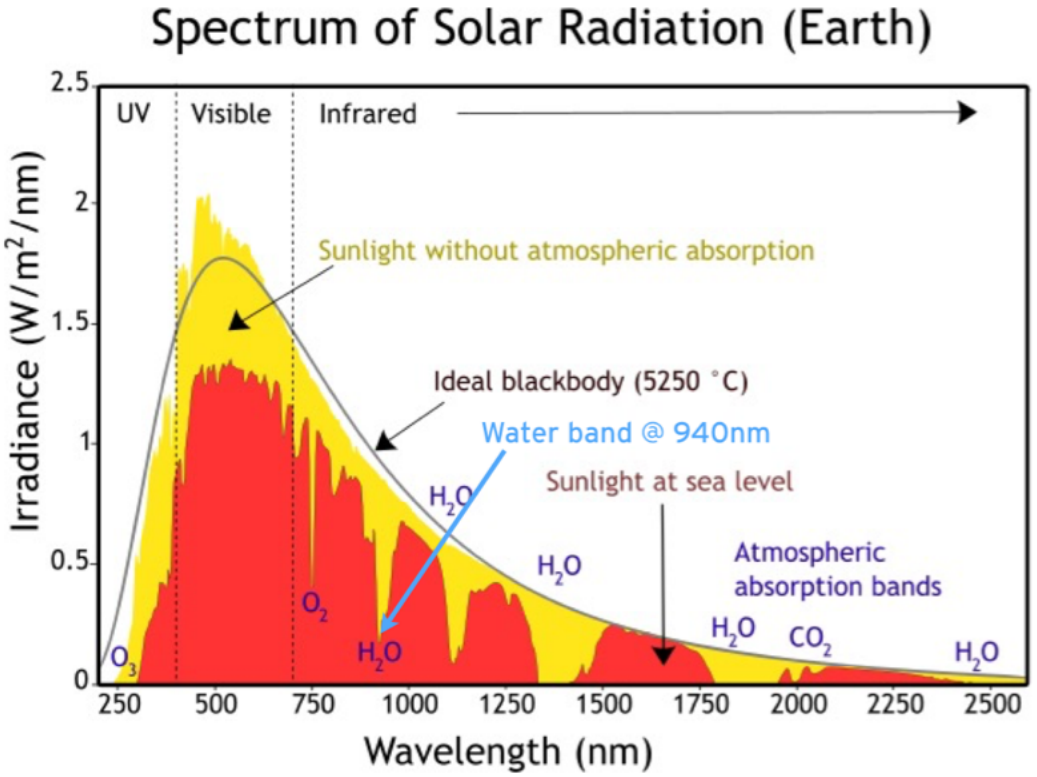
Applications

- Authentication
- Collision avoidance/3D mapping
- Augmented Reality

NIR light - Why is 940 nm better?

940 nm = water band

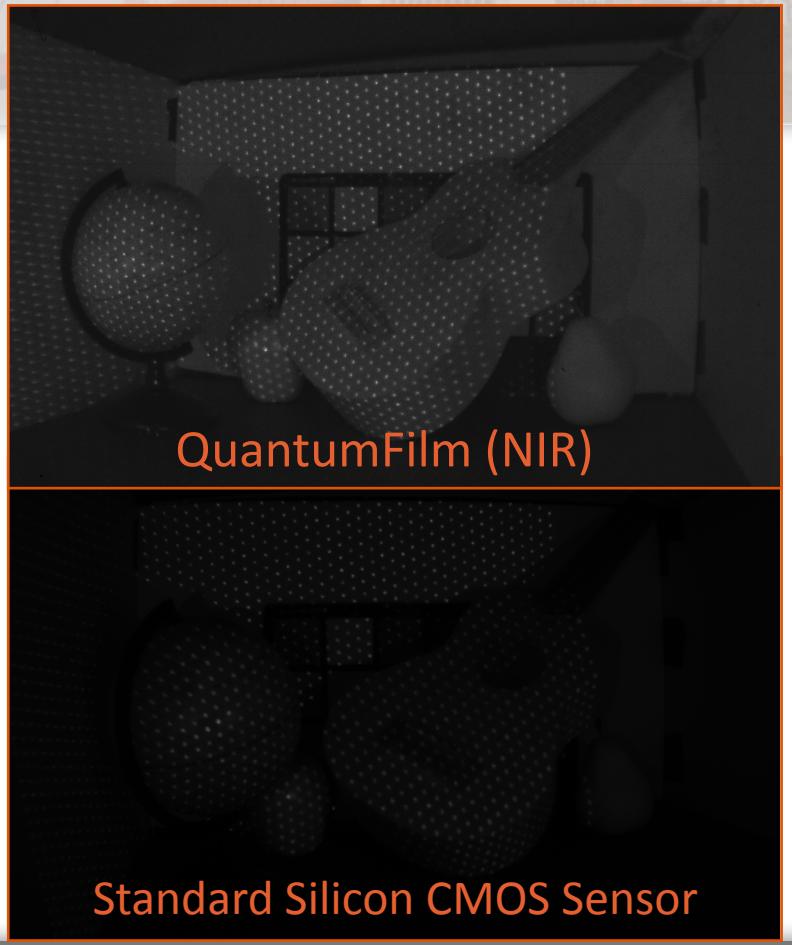
- Totally invisible IR light (no red glow after 880 nm)
- Minimizes structured light interference with human sight and sunlight



NIR QuantumFilm Advantages: Sensitivity

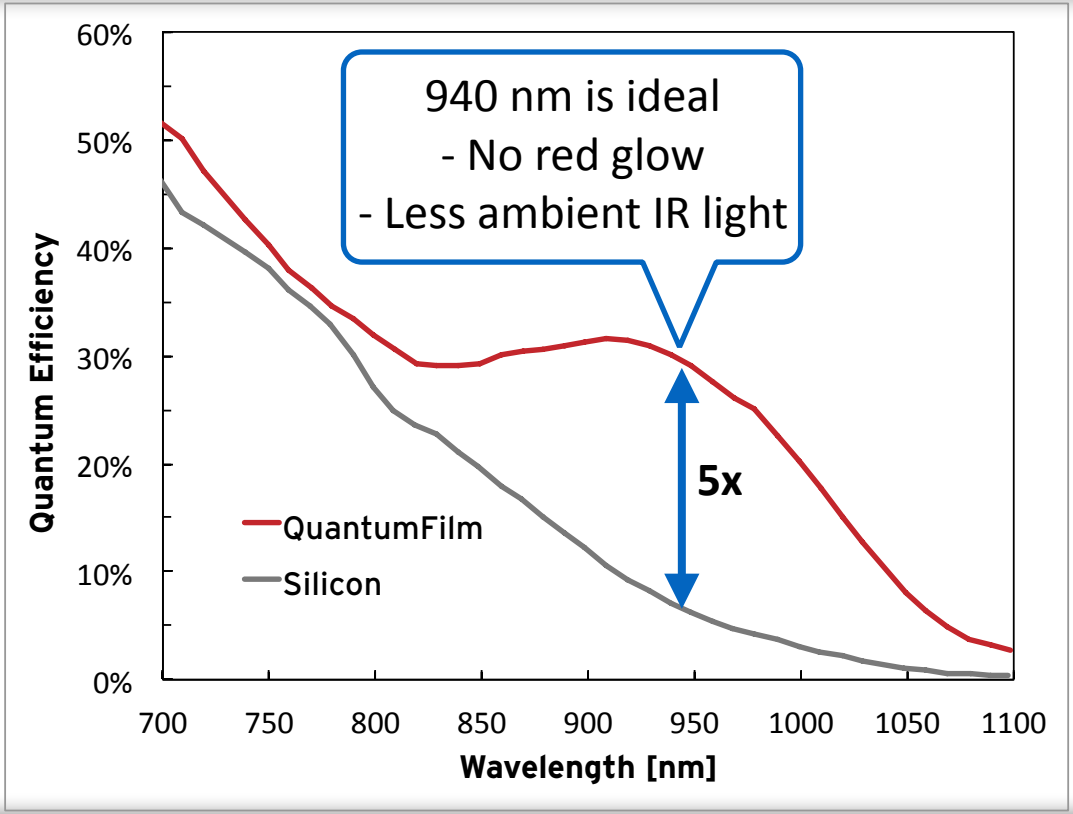
Higher sensitivity —> Increased NIR light absorption

- NIR QuantumFilm quantum efficiency (QE) at 940 nm = **35%**
- Silicon QE at 940 nm = **8%**



NIR QuantumFilm Advantages: Sensitivity

- QuantumFilm has 5X sensitivity to NIR light at 940 nm
- Silicon sensitivity decreases in linear fashion further into IR, hence past reliance on 850 nm (visible) over 940 nm (invisible) operation



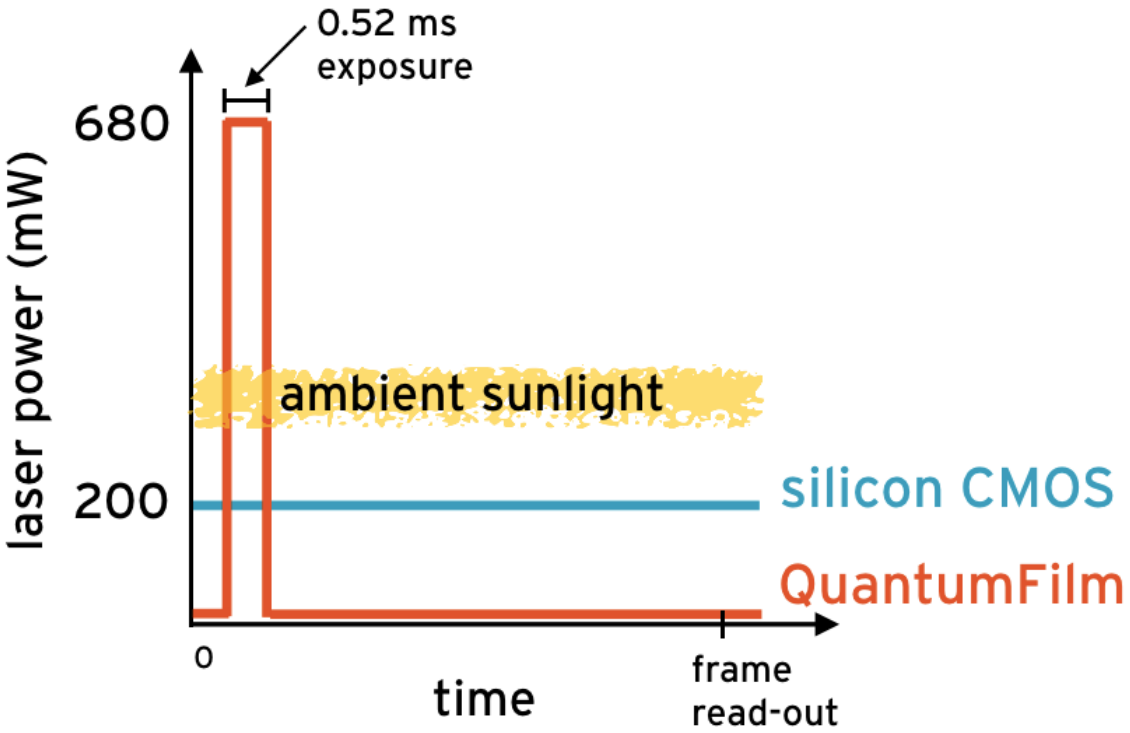
NIR QuantumFilm Advantages: Resolution

Higher Sensitivity —> Smaller Pixels —> Higher Resolution

- QuantumFilm NIR sensor pixel size = **1.1 µm**
- Silicon NIR sensor pixel size = **3 µm**

Drone with structured light (850 nm) at 10 m distance.

NIR QuantumFilm Advantages: Global Shutter - Power Savings



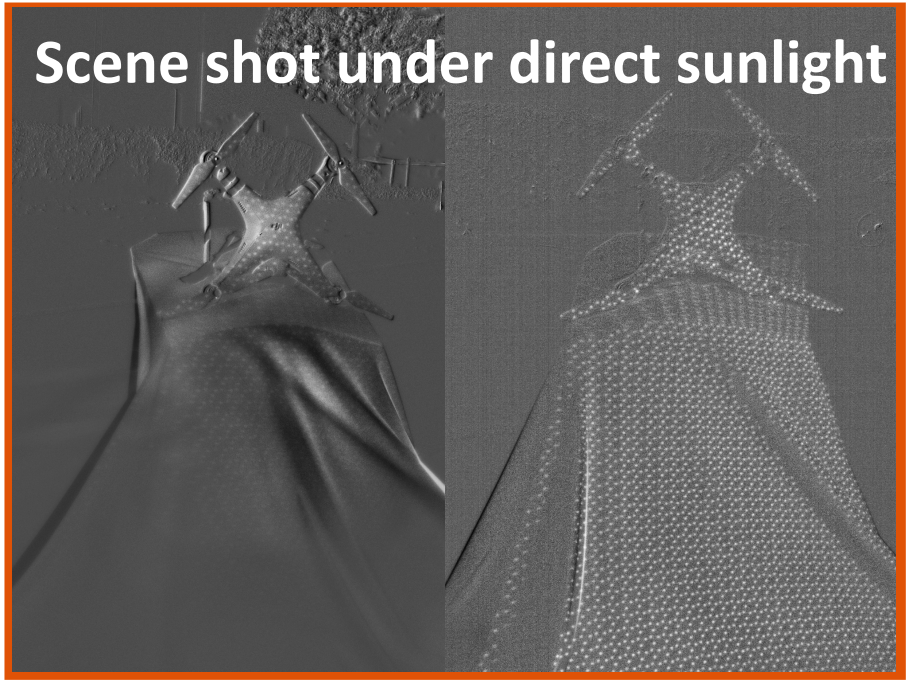
QuantumFilm's global shutter minimizes system power usage

- QuantumFilm camera system laser power consumption = **8 mW**
- Silicon camera system laser power consumption = **200 mW**

NIR QuantumFilm Advantages: Global Shutter - Outdoor Performance

Global shutter + high sensitivity enables NIR applications outdoors

- >50% of sunlight is IR
- Saturation prevents silicon NIR sensor operation outdoors
- Pulsing at a higher peak power allows for **99% sun irradiance rejection**

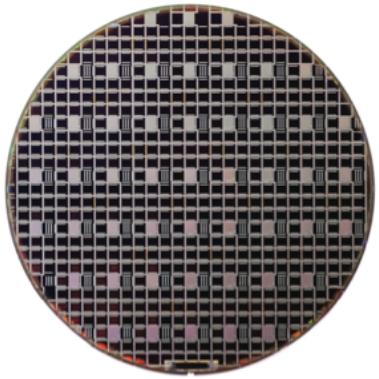


Silicon RS 850 nm
No structured light info

QuantumFilm GS 850 nm
Valid structured light info

The QuantumFilm Development Process for Multispectral Cameras “from dots to images”

QuantumFilm



QuantumFilm wafer integration

QuantumFilm camera modules

Integration into mobile, IoT and Pro platforms

Thank you!

shot with QuantumFilm for Visible

InVisage Technologies, Inc.

shot with QuantumFilm for NIR